Short Communication

Application of the Mechanistic Kinetic Model to Data from Conventional Batch Solids Mixers

L. T. FAN

Department of Chemical Engineering. Kansas State University, Manhattan. KS 66506 (U.S.A.)

F. S. LAI

U.S. Department of Agriculture, Agricultural Research Service, U.S. Grain Marketing Research Center, Manhattan, KS 66502 (U.S.A.)

Fan *et al.* [1] proposed a mechanistic kinetic model of the mixing process of segregating solid particles in motionless mixers. The model is analogous to the kinetic expression of a typical autocatalytic reaction and contains three parameters as shown below.

$$M = 1 - \exp(1 - K_1'N) - \frac{\rho\,[\exp(\beta'N) - 1]}{1 - (\rho/\alpha)\exp(\beta'N)}$$

where M = degree of mixedness, K_1', K_2' and K_3' = parameters in the mechanistic kinetic model, t = time of mixing, cN, N = number of rotations, c = proportional constant between t and N, $\rho = K_2'/K_3'$, $\alpha = \sigma_\infty^2/\sigma_0^2$, $\beta' = K_2' + K_3'\alpha$, σ_0^2 = variance at $t = 0$, and σ_∞^2 = variance at $t \to \infty$.

The model, however, has been tested only with experimental data obtained with motionless mixers. We have now applied the model to data from conventional rotary drum mixers [2] and from conical hopper mixers [3].

The data for the rotating drum mixer [2] are summarized in Table 1. The particles of coal and salt in cases 1 through 3 differ both in size and density, and those in cases 4 through 7 differ only in density; the rotating speeds are systematically varied in the latter four cases. Individual data points are plotted in Figs. 1, 2 and 4, and the curves in these figures represent the model of Fan *et al.* [1]. In Fig. 1, for cases 1 through 3, the model and data points agree satisfactorily. The satisfactory agreement can be observed either by inspection or through the comparison of

TABLE 1

Parameters of the mechanistic kinetic model for drum mixers with axis of rotation inclined at 23° to the horizontal (experimental data from Coulson and Maitra [2]). Length of mixer 22.5 cm, diam. 15 cm

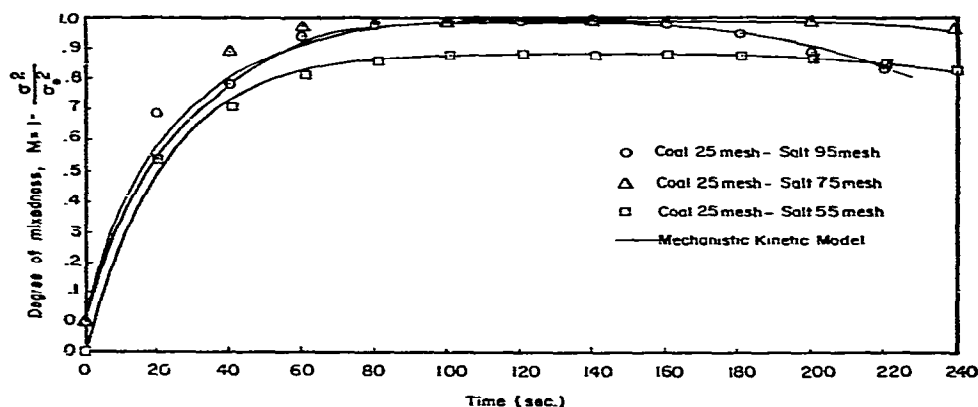| Case	Particle	Size (mesh)	Feeding method	Mixer r.p.m.	Parameter of the model			Standard deviation of residuals (computer–observed)
					K_1' (sec^{-1})	$K_2' \times 10^4$ (sec^{-1})	K_3' (sec^{-1})	
(1)	coal salt	25 95	top bottom	55	2.521	2.312	2.508	0.0631
(2)	coal salt	25 75	top bottom	55	2.477	3.895	2.014	0.0550
(3)	coal salt	25 55	top bottom	55	2.786	2.455	1.540	0.0162
(4)	coal salt	70 70	top bottom	23	0.9143	87.33	3.35 × 10^{-5}	0.0147
(5)	coal salt	70 70	top bottom	42	2.070	47.25	3.073 × 10^{-5}	0.0195
(6)	coal salt	70 70	top bottom	55	3.097	82.40	1.998 × 10^{-5}	0.0594
(7)	coal salt	70 70	top bottom	80	4.796	140.4	3.429 × 10^{-5}	0.00981

284

Fig. 1. Mixing curves for components of different particle sizes in drum mixers at 55 r.p.m. (Coulson and Maitra [2]).
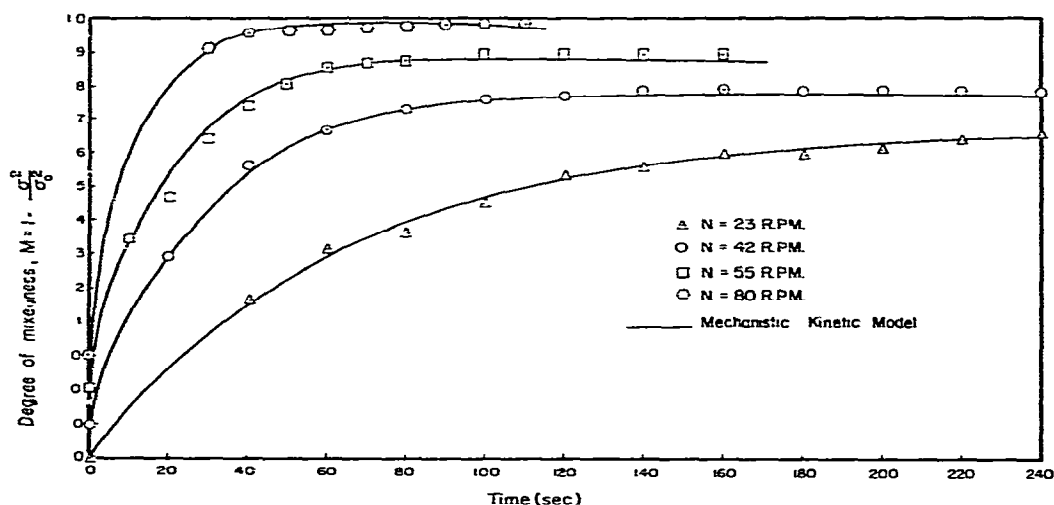

Fig. 2. Mixing curves for components of the same size with different densities in drum mixers at various r.p.m. (Coulson and Maitra [2]).
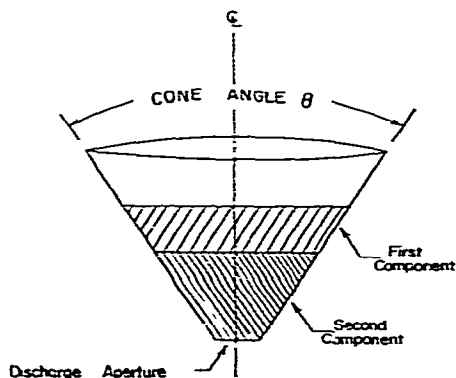

Fig. 3. Conical hopper mixer (Rose [3]).

the standard deviation of curve fitting, which is defined as the standard deviation of residuals (computed–observed). The values of the standard deviation of curve fitting are given in the last column of Table 1. In Fig. 2, for cases 4 through 7, agreement between the model and the experimental data is excellent. The best-fit parameters of the model are also given in Table 1. For the conical hopper mixer (Fig. 3), the number of revolutions of the cone corresponds to the "time". For a cone angle of less than 28°, mixing action does not occur. When the model and the experimental data for the conical hopper [3] are compared (Fig. 4), agreement is satisfac-
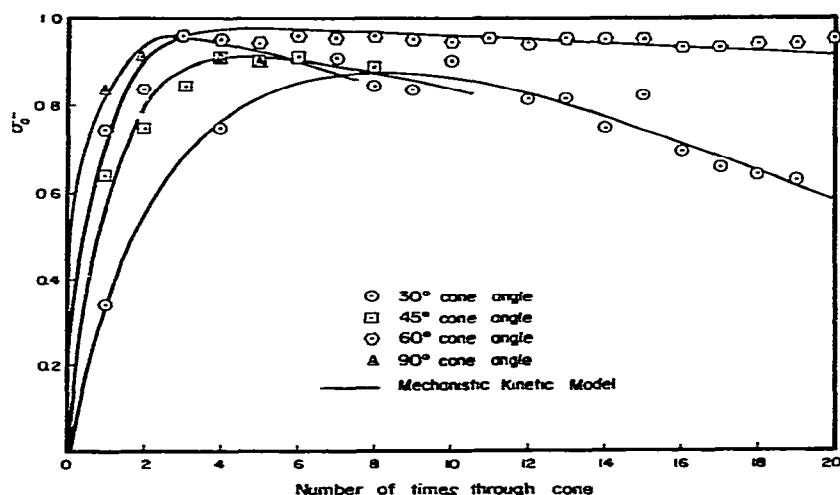
Fig. 4. Mixing curves for components of different particle sizes in conical hopper mixers with various cone angles (Rose [3]).

TABLE 2

Parameters of the mechanistic kinetic model for the conical hopper mixer (experimental data from Rose [3])

Cone angle (°)	Parameter of the model			Standard deviation of residuals (computed-observed)
	K' $(\sec^{-1})$	$K'_2 \times 10^4$ $(\sec^{-1})$	K'_3 $(\sec^{-1})$	
30	0.3948	68.25	0.3114	0.0346
45	0.9005	1799	0.9148×10^{-5}	0.0417
60	1.242	42.12	0.1828×10^{-5}	0.0247
90	1.849	161.2	0.2807×10^{-5}	0.0374

tory. The values of the standard deviation of curve fitting together with the best-fit parameters are listed in Table 2.

The model apparently predicts reasonably well the degree of mixedness, with the rotary drum or conical hopper mixer, as a function of time. The estimated parameters of the model appear to be functions of the particle size difference, structure of the mixer, and operating conditions.

ACKNOWLEDGEMENTS

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REFERENCES

1 L. T. Fan, H. H. Galves-Arocha, W. P. Walawender and F. S. Lai, A mechanistic kinetic model of the rate of mixing segregating solid particles, Powder Technol., 12 (1975) 139.
2 J. M. Coulson and N. K. Maitra, The mixing of solid particles, Ind. Chem., 26 (Feb.) (1950) 55.
3 H. E. Rose, A suggested equation relating to the mixing of powders and its application to the study of the performance of certain types of machine, Trans. Inst. Chem. Eng., 37 (1959) 47.